

## ANSWERS: Rate of Reaction and particle theory

1) When a metal carbonate reacts with an acid, carbon dioxide gas is released. This gas causes the balloon to inflate. It is faster when powder is used, because the surface area of the powder is greater. Because there is more surface area, there is more surface with which the HCl particles can collide. Because more collisions occur more frequently, the rate is faster, and CO<sub>2</sub> will be generated more quickly.

One way of making the reaction occur faster is to increase the concentration of the acid used. When this happens there are more HCl particles in the same volume of acid, and therefore there is a greater chance of collisions occurring more frequently, and so the rate of reaction is faster. Because the rate is faster, CO<sub>2</sub> is produced more rapidly, and the balloon inflates faster.

OR

The other way is to increase the temperature of the acid. When this happens, the HCl particles move faster; because they are moving faster, there is a greater chance of collisions occurring more frequently, and so the rate of reaction is faster. Because the rate is faster, CO<sub>2</sub> is produced more rapidly, and the balloon inflates faster.

Hydrochloric acid + calcium carbonate → calcium chloride + carbon dioxide + water.



2) a) The factor being investigated is surface area of the calcium carbonate / marble chips.

b) In section A of the graph the rate is fastest as there are more collisions between the HCl and CaCO<sub>3</sub>. This is because at the start of the reaction there are more particles available for collision. In section B the rate of reaction is slowing down as the number of particles available for collision is becoming fewer as some of the HCl and CaCO<sub>3</sub> have already collided and have been used up, therefore fewer particles and therefore fewer collisions.

In part C the reaction has stopped, as all of the reactants (or one of them) have reacted, and therefore there are no particles present that can collide and react.

c) The rate of Experiment 1 is faster as the slope in section A of the graph is steeper than in Experiment 2. It is faster because when smaller chips are used, the surface area of the chips is greater. Because there is more surface area, there is more surface for the HCl particles to collide. Because there are more collisions occurring more frequently, the rate is faster.

3) The reaction is faster at the higher temperature, because the  $H^+$  ions have more kinetic energy, and therefore are moving faster. When they are moving faster, there will be more collisions, and more of these collisions will be effective, as the particles will collide with more energy.

Line B represents the faster reaction, as it is steeper at the start. This represents the reaction carried out at  $40^{\circ}C$ . Both lines become horizontal at the same point on the Y-axis, as this is when both reactions have finished, ie one of the reactants has been completely used up and therefore no more gas is produced. Both finished with same amount of gas produced, as both reactions had the same amount of reactants to start with.

4) a) Fizzing / bubbling occurs, marble chips decrease in size, heat is produced.

b) **Why mass decreases**

The marble chips decreases as one of the products is  $CO_2$  gas. This gas escapes and so the mass of the flask and contents is reduced.

**What's happening**

As the reactant particles collide, they form product particles. As the reaction proceeds, there are fewer and fewer reactant particles left to collide and so the rate of reaction becomes slower.

At the start (section X) of the reaction, more product particles are being formed, then more gas is being formed, therefore more gas escapes at first and so the mass of the flask and contents decreases more rapidly. At X, the rate of reaction is fast but decreasing with time.

In section Y there are now fewer (less) reactants and so there are fewer collisions per second (unit time) and so less product is formed, ie less gas being released, so the mass does not decrease as rapidly. At Y, the rate of reaction is slow and slowing.

In section Z the reaction has stopped, as one of the reactants (marble chips or HCl) has run out, so there are no particles left to react.

c) When more concentrated acid is used, there are more acid particles in the same volume of the acid. Because of this, there are more particles to collide with the calcium carbonate. Because there are more to collide, the rate of reaction is faster.

5) a) Explanation of levelling of graph:

b) As the reactant particles collide, they are converted into product particles. Initially many gas molecules are produced, but as the reaction proceeds there are fewer and fewer reactant particles available to collide, so the volume of gas produced decreases and eventually no gas is produced.

(Most likely the supply of  $\text{H}^+$  ions in the solution will be exhausted before the marble chips disappear.)

Completing a word equation:

Hydrochloric acid + calcium carbonate  $\rightarrow$  calcium chloride + water + carbon dioxide

Completing a symbol equation:



c) Comparison of rates of reaction:

The reaction rate will be faster with the powdered marble than when the chips were used. More gas will be produced each minute. The reaction itself will be completed in a shorter period of time.

### Explanation of effect:

There are more reactant particles immediately available to react because the surface area of the powder is greater than that of the chip. There is greater exposure of the marble particles so there are more available for the acid particles / hydrogen ions /  $\text{H}^+$  ions to collide with.

This means there will be more (effective) collisions per second / more frequent collisions between the acid particles and the ions in the calcium carbonate powder, leading to an increase in the rate of the reaction and the reaction will be completed sooner.